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From the Definition of Colours Attributes to Build a Semantic Space: Application to a Sport-Health Dialogical Context of Use

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Abstract

The integration of user perception into the design process has become necessary to provide the best experience to users. All methods focusing on the interpretations of products are based on the same principle: identifying relationships between a semantics and physical attributes of products within a product domain. Sometimes this domain makes the definition of these relations more complex as for a dialogic context of us due to the lack of existing product. We propose in this paper a method to define a semantics directly from products attributes in regards with a dialogic product domain.

Keywords: user experience, user-centred design, semantics, product design

1. Introduction

It is well accepted that nowadays a product is not only an artefact but an experience which starts by discovering the product and its appearance. So, designers' choices concerning colours, materials and more generally product attributes, strongly determine the user's experience. Each attribute is felt and perceived by users, providing them meanings, affects and emotions. People use mainly words to express themselves about this perception. These words are called semantics and compose a "semantic universe" (Alcántara et al., 2005a) also called "Semantic Space" (Schütte et al., 2008). Considering product semantic as a methodology, we can mention the Sensory Design, which focuses on the semantics related to the sensory response the Semantic Approach focusing on the semantics of the cognitive response (Petiot and Yannou, 2004), and Emotional Design observing the semantics of the emotional response. In a more global way, we can also mention Kansei/Affective Engineering which allows to consider the semantics of affective, emotional and sensorial responses (Nagamachi, 1989; Schütte et al., 2008).

All these methods have in common to follow the same principle illustrated in (Figure 1). The main stage of this principle (framed in Figure 1) consists in defining two spaces, a space of physical attributes and a semantics one, and identifying the links between.

In this way, the two spaces of semantics and attributes are closely linked. One cannot be defined without defining the other. It is possible either to construct the semantic space from the attributes space (Petiot and Yannou, 2004 Wu et al., 2017; Zhu et al., 2006) or the reverse (Alcántara et al., 2005b; Shieh and Yeh, 2015). It requires nevertheless to pay particular attention to the targeted product domain when defining them.

Depending on its nature, the building of a semantic space or an attribute space is further complicated. Regarding the design of sports products, they are designed not only as sport products, but also as health ones to fulfil users' needs. Two product domains, with two different perceptions are then involved in this design process. On one side sport is perceived good for health. On the other side, improving

performances of sportswomen/men may be perceived at the expense of their health. In this way, both domains (sport and health) appear complementary and opposite at a time. Despite this duality, some designers still try to design products regarding a hybrid products' domain merging both sport and health domains int one: a sport-health. This duality is called a dialogy, i.e., two entities, two principles that unite without losing their duality (Morin, 1990).

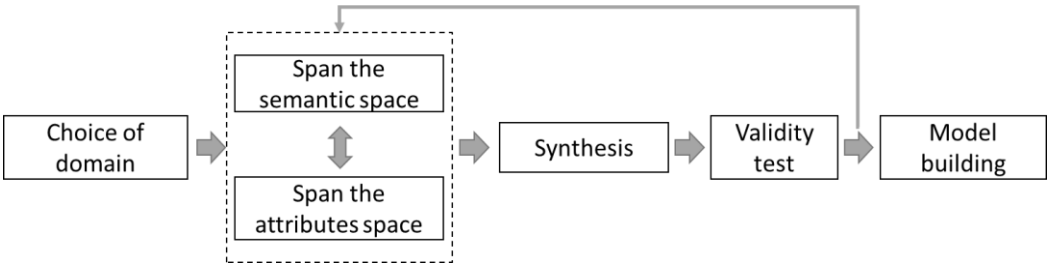

Figure 1. Affective engineering framework (Schütte *et al.*, 2008)

It means that a dialogical product domain is defined on its own. It does not necessarily reflect the product domains to which it refers. Sport and health products cannot be representative of the sport-health dialogical product domain. And sport-health products are not necessarily representative of sport and/or health domains. Moreover, sport and health product domains are nowadays well explored, and number of related products are observable. This is not the case for the dialogic domain. Due to the duality of its nature, existing products related are rare or even non-existent. As consequences, it becomes more complex to define both semantic and product attributes of a dialogical product domain due to this lack. How can designers compose the space of attribute without product to break down into relevant design elements? How can they define a space of semantics without products attributes to relate?

The space of attribute is commonly built by breaking down existing product into design elements. At beginning of the experience with the product, the discovery, these elements compose the product appearance. Three main categories of design elements appear then: shapes, materials, and colours. All these elements can nevertheless be used independently of existing products. Materials are categorised into families, colours into shades and shapes into geometries that designers can use. So, despite the lack of existing products, generic attributes can provide a first trend to define the perception of a dialogic product domain. Based on this observation, **we propose in this paper a method to define a semantic space directly from product attributes**.

Within the next section, we present methods to build semantics and product attributes spaces. Afterwards, we describe our proposed method to define semantics directly from product attributes and its application to a dialogical sport-health product domain.

2. Methods to define attributes and semantics spaces

While defining the perception of a product domain, a semantics and product attributes must be defined. A common method used for the semantics definition is the Differential Semantics (Alcántara *et al.*, 2005a; Osgood, 1952). It consists in (i) gathering a pool of semantics and afterwards (ii) establishing the embodiment of the semantic space.

About gathering a pool of semantics (i), different media are usable. It can be either magazines, ads, scientific papers, or online commentaries (Wang et al., 2018). This extraction can be also combined with interviews to enhance the semantic space. As example, Alcántara, Artacho, González and Garcia (2005) used 50 journals and magazines and interviewed 25 users to extract semantics. Combining sources allows to observe different point of view and so to reduce the possibility to miss semantics. According to Schütte, Krus and Elund (2008), all available sources should be used in regards with a product and its domain. Evaluation made by users and/or analysis performed by experts are then used to refine the pool of semantics to merge towards a Semantics Space.

During the Embodiment of the semantic space, semantics gathered are organized to observe trends and associations. We identified three uses of the Semantic Space and then three ways to represent it. The first one is a *Semantic Profile*. It is a representation of the global meaning conveyed by one product in

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regards with all the semantics making up the space. This representation is commonly used to evaluate an existing product to identify its strengths and weaknesses. From these understanding designers can improve the product design afterwards (Alcántara *et al.*, 2005b; Lallemand *et al.*, 2015). The second use is a *Product Mapping*. In this use, only several of the semantics of the space are focused. These are used to define the axes of a x-y graph and people position products regarding them. It is then possible to identify clusters of similarities between observed products and to extract trends concerning product attributes that convey the semantics of this map (Kongprasert *et al.*, 2008). The last use of the semantics we observe is the *Semantic Mapping*. In this use, results of the Differential Semantics allow to map all the semantics on a x-y graph and observe how they are related. Its use allows to refine the semantic space by eliciting semantics that are close in meanings (Petiot and Yannou, 2004) or if they are more suitable to translate the perception of a specific product domain (Millet *et al.*, 2020).

In spite of these various representations, we note that the construction of the semantic space relies on the expression of users and/or experts. In order to help them in this task, it is usual to use existing products as visual support (Alcántara *et al.*, 2005b; Petiot and Yannou, 2004; Wu *et al.*, 2017). The use of a visual medium presents the advantage to share a common basis for expression between all evaluators. Moreover, it makes it easier to evaluators to express themselves on their perception. Without visual support, they must remind themselves or imagine a product and the sensations it provides. An altered or partial sensation can then be evaluated. With a visual support, they do not have to call up memories and can express directly on what they observe and manipulate. For this reason, it appears more suitable to define a semantic space after having built a space of the product attributes.

About the product attributes space, a common way to build it consists in using existing products and breaking it down into key attributes. Regarding the shapes of products, it is possible to create a morphological matrix based on the product appearance. This matrix can be used to present the variation of the overall profile of a product (Becker *et al.*, 2011; MacDonald *et al.*, 2009; Petiot and Yannou, 2004) or to present basic geometrics that compose the observed product (Ngo *et al.*, 2012; Shieh and Yeh, 2015; Xue *et al.*, 2019). About materials, these attributes have the particularity of appealing to two of our senses: the sight and the touch. Thus, it is common to observe the building of the space of attributes based either on physical samples (Avramescu *et al.*, 2014) or only on visual representation of them (Maleki *et al.*, 2019). The last category of design element strongly impacting the perception is the colour. To build the product attributes space of colours, the main principle consists in decomposing the wheel of colour regarding its properties. It is possible to create a set of colours based on the RGB model or the HSV model. Because of the closeness to the perception of the human eye, the HSV model is preferred to compose a palette of colour product attributes (Casales-Garcia *et al.*, 2020; Wu *et al.*, 2017; Zhang and Zhu, 2009). For this purpose, it is common to realise combinations of the values of Hue (H), Saturation (S), and Value (V). It can be made by using mathematical model like fuzzy logic (Zhu et al., 2006) or manually (Wu et al., 2017).

Once these product attributes are defined, they are used as support to allow evaluators to express their perception of the product (Alcántara *et al.*, 2005b; Shieh and Yeh, 2015; Wu *et al.*, 2017). However, the selection of these attributes is linked to a specific product domain to identify key attributes more quickly. In the context of a hybrid product domain known as dialogic, we have seen that these products are rare or even non-existent, making the identification of key attributes more complex. Despite this, regardless of the type of element observed, we find that approaches breaking down existing products lead to extract generic or basic product attributes. It is then still possible to use these generic attributes directly to define a product attribute space when few or no products exist. Regarding materials, we can use the different families as defined by Ashby (2010). About shapes, basic geometrics elements (circles, squares,…) are usable (Xue et al., 2019). As for colours, we can use the shades composing the colour wheel (Wu et al., 2017).

Depending on the kind of attributes, our senses are differently involved. Perceiving materials involves not only sight, but also touch and smell. In the same way, shapes appeal to our sense of touch and sight, while colours only stimulate our sight. This allows to evaluate the perception of a product at different levels of details. The greater is the number of senses involved, the richer is the experience, and so more precise the expression of perception (Fenko et al., 2010). It requires nevertheless to use physical product or samples of attributes within an in situ or face to face experiment involving times and resources. For

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this reason, visual representations of these attributes are more common to observe while considering number of evaluators. Moreover, this is also due to the fact that sight is the predominant sense among those at our disposal (Fenko *et al.*, 2010; Schifferstein, 2006). This means that for material and shape attributes, their perceptions are partially evaluated. Only visual stimuli are considered and not tactile and olfactory ones. It implies that the resulting perception may be imprecise or even altered. In contrast, for colour attributes, the use of visual-only representations does not affect perception since they depend only on sight.
For these reasons, we focus in this paper on the colours attributes to illustrate the application of the proposed method to define a semantic space directly from product attributes.

3. Methodology

In this paper, we propose a method to define a semantic space based on colour attributes of products, considering a hybrid dialogic product domain. The method we propose presents two steps as illustrated in (Figure 2)**:**

- (i) The first one**,** identifying colours of the dialogical product domain
- (ii) Extracting semantics of the dialogical product domain.

Whitin the first step (i), we aim to extract colours specific to the dialogical domain from a set of colours with the help of users. At this stage, we invite participants to associate shades with sport-health product domain. The colours extracted are then confronted to a pool of semantics within the second steps (ii). In this second step, we invite participants to associate semantics to colours they consider representative of the dialogical domain. Based on the associations made by participants we aim to extract the semantics of the dialogical product domain directly with its relations with the colour attribute**.**
We designed a survey to apply this method within the case of study of a sport-health product domain.

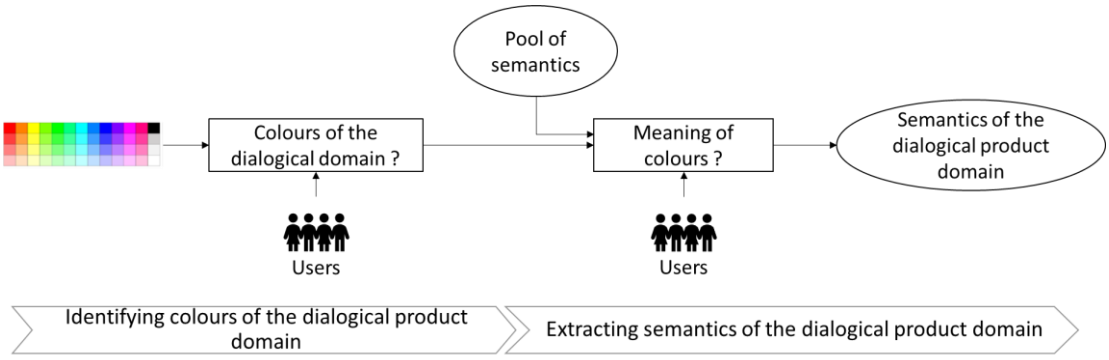

Figure 2. Steps of our methodology

3.1. Building of the colour set

Before asking users to propose colours of the dialogical product domain, it is necessary to present a colour set. Based on the Munsell model, we adapted the approach of Wu et al. (2017) for this purpose. We segmented the colour spectrum regarding first the Hue (H). We extracted 12 hues (see Figure 3). We started from the hue H_0=0 (red case on the left in Figure 3) and selected each new hue by incrementing the value of H by 30. As example, the 3rd hue extracted presents the value H_3= 30*2 = 60, i.e., a yellow.

Figure 3. Natural hues composing our colour set

Once the hues are defined, we broke them down regarding the Value (V) and the Saturation (S). To reduce the cognitive load during the survey, we choose to break hues down only regarding the

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Saturation first. So, we fixed the Value to 100% allowing to keep the natural brightness of each hue and selected 4 values of Saturation: S1=25, S2=55, S3=75, and S4=100. This choice was motivated by the fact that the Value (V) represents a measure of the brightness. In this way, the Value darkens or lightens a shade and can be assimilated to a black and white scale (with S=0). This is this sense in which we use the Value. We added 4 colours from black to white (last column in Figure 4) to consider the achromatic colours. We created then a set composed of 52 colours as illustrated in (Figure 4). Each of these colours were collected from the wheel of colour developed by Adobe in HSV mode.

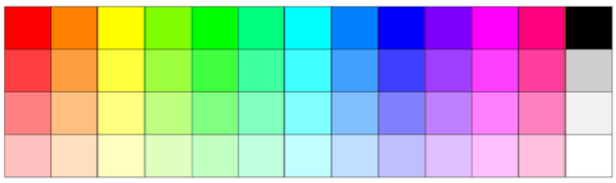

Figure 4. Colour palette designed for our experimentation

3.2. Design of the survey

The survey we designed is composed on three Tasks:

- T1: Associate each colour to one product domain
- T2: Associate or not each colour to the sport-health product domain
- T3: Associate each semantics to a colour regarding the sport-health product domain

With the two first tasks, we aim to identify specific colours of the dialogical product domain while we seek to extract the semantics from these colours of the dialogical domain in the last one.

In the first task (T1), we want to observe hues specific to one of the contexts composing the dialogic product domain. To do so, we proposed participants to first observe only natural hues of the set created. It represents the 12 "pure" hues (S= 100%) in the first line of the (Figure 4), in addition with the black and white hues. They are invited to associate each of these 14 colours with only one of the following product domains: *Sport*, *Health*, *Sport-Health* and *None*.

About the second one (T2), we want to extract not only hues related to the dialogic product domain but also their shades. For this purpose, we asked them to associate the shades of the colours set with only one of the following categories: *Sport-Health* or *Not Sport-Health.* In order to limit the visual and cognitive load during the task, we picked up 12 colours out of the 52 presented in (Figure 4) to each participant. We also ensured the assessment of each 52 colours by implementing rotations to counterbalance the apparition of each colour. We took care that each colour attribute was shown the same number of times to the sample of participants. We also ensured that none of these colours were presented with the same colour attributes between each participant to avoid evaluations of colours' associations.

With the last task of the survey (T3), we aim defining semantics adapted for the dialogical product domain from the colours identified in the previous task (T2). So, we asked participants to associate (or not) each different semantic descriptors to the 52 different colours of the set. So, a semantic descriptor could be associated with one, none or several colours. As for the previous task, we limited the cognitive and visual load by presenting only three descriptors at a time per participant and implemented rotations to avoid predominance of one colour or the evaluation of colours associations.

The sample is composed of 63 words focusing on the sport and health product domains (Millet et al., 2019).

3.3. Participant profiles

We target a broad profile of the population to cover the profiles of users consuming sport and/or health products. No restrictive criteria are therefore applied.

However, perception can be influenced by various factors such as culture and knowledge (Krippendorff, 2005). A designer who is an expert in the design of sport-related products is more likely to know the specifics of this context than a novice. The knowledge accumulated allows them to better identify the details of a product (Ahmed et al., 2003; Deininger et al., 2017). Similarly, a user

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who has already experienced a product will pay more attention to certain aspects of the product compared to a user discovering the product for the first time who may not be aware of these aspects. For these reasons, we asked participants to provide, in addition to their age and gender, their sports profile and their professional activity. Concerning the sports profile, we ask them to provide information on:

- Their frequency of practice: *Daily, Weekly, Monthly, Occasional, Never*
- The sport practised in the form of an open question
- Their estimated level: *Athlete, Confirmed, Amateur, Novice*

Concerning professional activity, participants indicate their occupation and the industrial sector.
The survey involved colours and their variation of saturation. Consequently, we made sure that each participant indicated the presence of visual disorders that could impact the results such as *Daltonism, Achromatopsia* or *Other Visual Disorders*.

4. Results & Analysis

4.1. Description of the participant sample

We collected responses from 223 participants including 122 of whom performed all the tasks.
The sample is composed of 44.3% female and 55.7% male. The youngest was 15 years old and the oldest 80 years old. The median age is 30 years, the first quartile is 25 years, and the third quartile is 43 years. Half the sample is between 25 and 43 years.
The participants are (1) engineers (18.9%), (2) students (18%), (3) teachers (13.9%), (4) doctoral students (6.6%) or retired (6.6%) and (5) researchers (5.7%). All the occupations mentioned, which make up less than 5% of the sample, were grouped together in an "Other" category, which represents 30.3% of the observed sample. Participants in the sample work mainly in a sector that is neither health nor sport-related (88.5%). Participants working in a health-related sector of activity represent 8.2% of the sample. Those working in a sport-related sector make up 1.6% of the sample, as do those working in a sport and health-related sector.
More than half of the sample practises physical activity on a regular basis (73%), which 52.5% weekly and 20.5% daily. More than half of the sample (58.2%) considers itself to be an amateur.
Finally, most of the participants had no visual impairment (87.7%). Only 1 participant is colour blind and 11.5% of the sample have visual disorders that do not affect colour perception such as myopia.

4.2. Results of the definition of sport-health colour attributes

With the two first tasks, we aimed to identify colours specific to the sport-health dialogical product domain to extract afterward the semantic related. We first asked participants to associate each of the 14 primitive colours with one of four usage contexts: *Sport, Health, Sport-Health and None*. We counted 156 participants who performed the first task (T1).
Considering each hue, we observe the frequencies of associations with the different contexts (illustrated in Figure 5). Among the 14 hues presented, all were associated at least in 30% of the cases with the *Sport-Health* product domain. The hue with the lowest frequencies of association with this context is #ff00ff (■). Hues #ffffff (□) and #007fff (■) were associated in more than 67% of cases with the *Sport-Health* product domain and hue #0000ff (■) in 62,2% of cases.
About the *Sport* product domain, hues #00ff00 (■), #ffff00 (■), #ff8000 (■), #ff0000 (■), #ff007f (■), #ff00ff (■), #7f00ff (■) and #000000 (■) were associated at least in 33% of cases with it. Among them, 3 were more associated with the *Sport* product domain than with the *Sport-Health* product domain: #ff8000 (■), #ff007f (■) and #ff00ff (■).
We note that for each hue, few associations were made with the *Health* domain. The maximum observed is 22%.
So, all of the proposed hues tend to be associated with the *Sport-Health* product domain. Among these, some have "strong" tendencies to be perceived as belonging to this context. This is the case of "cold" colours, more particularly linked to the blue tint (#007fff (■), #0000ff (■)), and white #ffffff (□).

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We note that participants profiles have quite no influences on these results. Chi² tests between the profile criteria (age, gender, level of sport and frequency of sport) and the associations made with the different categories reveals that only the age seems to influence the results and only regarding the *Health* product domain (F (39) = 54,74, p = 0.048*). It appears that the lower is the age, the more Green hues are associated. So, based on these results, we observed a first trend regarding three hues strongly related with the dialogical domain.

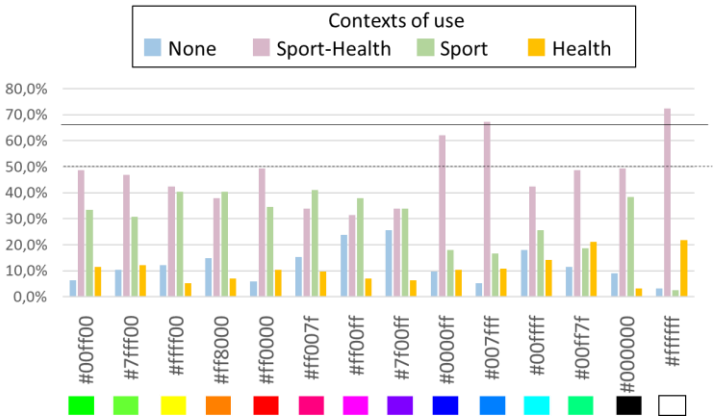

Figure 5. Frequencies of associations with the contexts of use made by participants regarding natural hues (value at 100%)

With the task 2 (T2), we asked each participant to associate 12 of the 52 colours of our set with one of the following categories: *Sport-Health* or *Non-Sport-Health*. In total, 129 participants performed this task. The minimum number of associations with the *Sport-Health* product domain observed for a colour is 21 (#00ffff ■) and the maximum is 41 (#0000ff ■). On average, a colour attribute has 30 associations with the *Sport-Health* product domain.

In total, 48 colours out of 52 were associated half the time with the *Sport-Health* product domain. Among them 29 colours are associated in more than 67% of cases and 19 colours between 50% and 67% of the cases. By repositioning the 29 colours with highest frequencies of associations on the colour wheel, we observe that blue and green colours are mostly associated with the *Sport-Health* product domain (marked with a black dot in Figure 6). About the achromatic colours, only one colour does not appear suitable for the dialogical product domain: #ffffff (■)

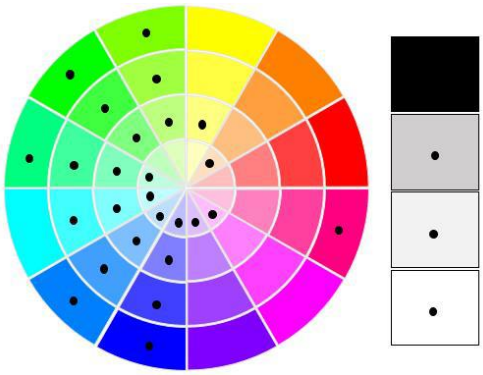

Figure 6. Overview of colours relevant to a sport-health dialogical product domain according to participants

So, "cold" tones seem then relevant to apply in the sport-health dialogical product domain according to participants. These results confirm the trends observed at the previous task. According to them, the method we propose allows to extract first colours of the dialogical domain and afterwards to validate and enhance this extraction by also extracting the shades of colours.

Within the next section, we present the results of the second step of the proposed method consisting of identifying the semantics they put on these colours in regards with the dialogical domain.

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4.3. Results of the definition of sport-health colour attributes

To extract the semantics related to Sport-Health colours, we ask participant in a third task (T3) to associate (or not) different semantic descriptors with one or more of the 52 colours proposed.
We gather the answers of 128 participants for this task. We observed a total of 1814 associations of semantic descriptors with the set of colours. Among them, 1115 (61%) were with colours perceived as *Sport-Health* (previously defined with T2).
On average, 13 semantic descriptors are associated with one Sport-Health colours. Among the descriptors associated with *Sport-Health* colours, we note the following:

- 15 descriptors were associated less than 50% with *Sport-Health* colours
- 26 descriptors were associated between 50% and 67% with *Sport-Health* colours
- 22 descriptors were associated at least at 67% or more with *Sport-Health* colours

Of these 22 descriptors (see Figure 7):

- 12 have more than 50% of their associations made with blue shades: Accessible, Attractive, Comfortable, Discreet, Efficient, Formal, Soft, Pleasing, Prevention, Clean, Robust and Tight
- 2 have more than 50% of their associations made with green shades: Fashion and Modern
- 1 semantic descriptor has an association frequency with a colour equal to 50% of all its associations: Clean with #0000ff (■)
- 3 semantic descriptors have an association frequency higher than 25% with a specific colour: Clean (25%) with #3f3fff (■) and (25%) with #007fff (■) / Robust (30%) with #80bfff (■) / Specific (33%) with #ffffff (□)

So, among these 22 semantic descriptors, half present tendencies to be associated with a specific colour. It means that these colours can be used to convey these semantics regarding the sport-health dialogical context of use. We observe that semantics with the "strongest" associations with a specific colour are linked with natural hue (i.e., Saturation Value at 100%): #007fff (■), #ffffff (□) and #0000ff (■). This recalls the results observed in the first steps of the methods. These colours were indeed the more associated to the dialogical product domain and thus it can the one on which users can express more easily.

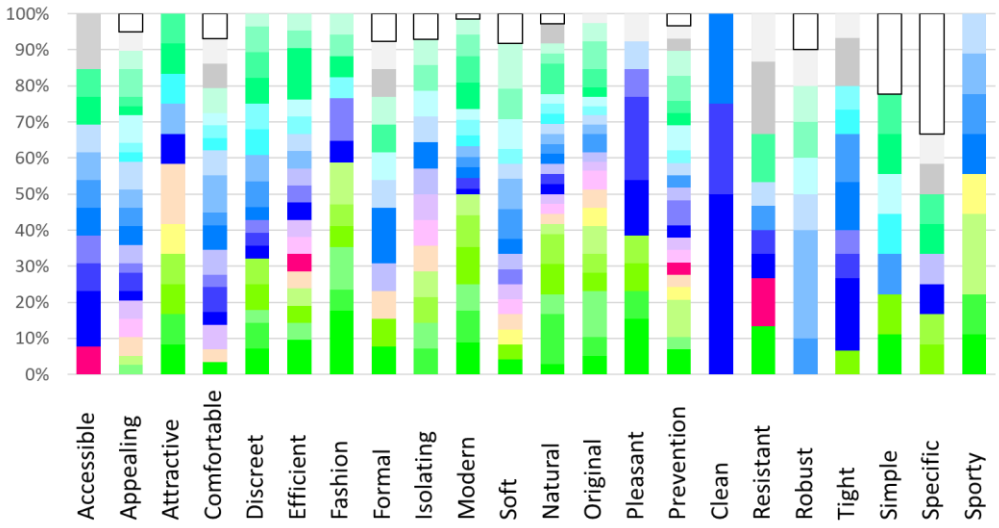

Figure 7. Proportions of sport-health colours associated per semantic descriptors (only descriptors presenting 67% of associations with sport-health colours).

So, results of the task 3 shows that the last step of the proposed methods allows to extract semantics directly from colours specific of a dialogical domain (22 within this case of study).

5. Conclusion & Discussion

We proposed in this paper a method to build semantics extraction by the definition of product attributes for hybrid products that are linked to dialogical domains. Our method is based on an online survey in

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two phases: the first step is the definition of product attributes relevant for the product domain targeted and then the second step is concerning the identification of semantics based on the products' attributes previously defined

To illustrate the method a case study is presented concerning the definition of colour's attributes of sport-health dialogical product domain. By using the method with 223 participants, we identified 29 colours adapted to a sport-health product domain. Then the method allows the extraction of 22 semantics in total, directly from these specific colour's attributes. So, based on these results, we demonstrate how the proposed method support the definition of semantics of a dialogic product domain from colours attributes without the help of existing products as visual support. We believe that this proposition is a first step to help designers to anticipate the way can be perceived a new hybrid product domain. This method can be easily applied to various types of products in dialogical domains. By using generic product attributes rather than existing products, it allows designers to anticipate and define the perception of a product domain that is not yet well known to users. We believe that by applying this method, user expectations will be better considered in the design process to improve the product experience. Particularly in the context of a dialogical or at least hybrid product domain, designers can use the results of this method to orient the design towards the hybrid domain or its sub-domains and thus reduce the risk of misinterpretation by users and thus rejection of the product.

We are nevertheless conscious that results observed in this study are based on first tendencies that need to be confirmed by future experimentations. Our limitations are due to the number of items surveyed and the number of participants who responded to the questionnaire. Due to the rotations put in place during the creation of the questionnaire, the number of participants should be improved to observe strongest trends. Even if 122 participants have completely answered the questionnaire, we still recommend increasing the number to refine the results observed here and verify these trends.

Within this study, we especially focus on the dialogical sport-health context of use. With the first step of the method, we were able to extract trends about sport-health colours. However, we did not extract colours related to the sub domains of the dialogic ones. We extracted trends about natural colours related to the sport domain, but none related to the health. The colours of the health domain may then be hidden within the sport-health one. We consider therefore to repeat this method on the health domain and the sport domain separately to refine these results.

A last point, we focus only on colours in this work concerning the product's attributes. The perception of products requires also to consider all stimuli (material, shapes, textures…) impacting the perception. We know that applying this method also on these product attributes is necessary to fully define the space of attributes of a dialogic product domain and thereafter better define its semantics. This will be the subject of future work to help define the perception of the complex or new product domains like dialogical ones.

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